Wiser: Increasing Throughput in Payment Channel Networks with Transaction Aggregation

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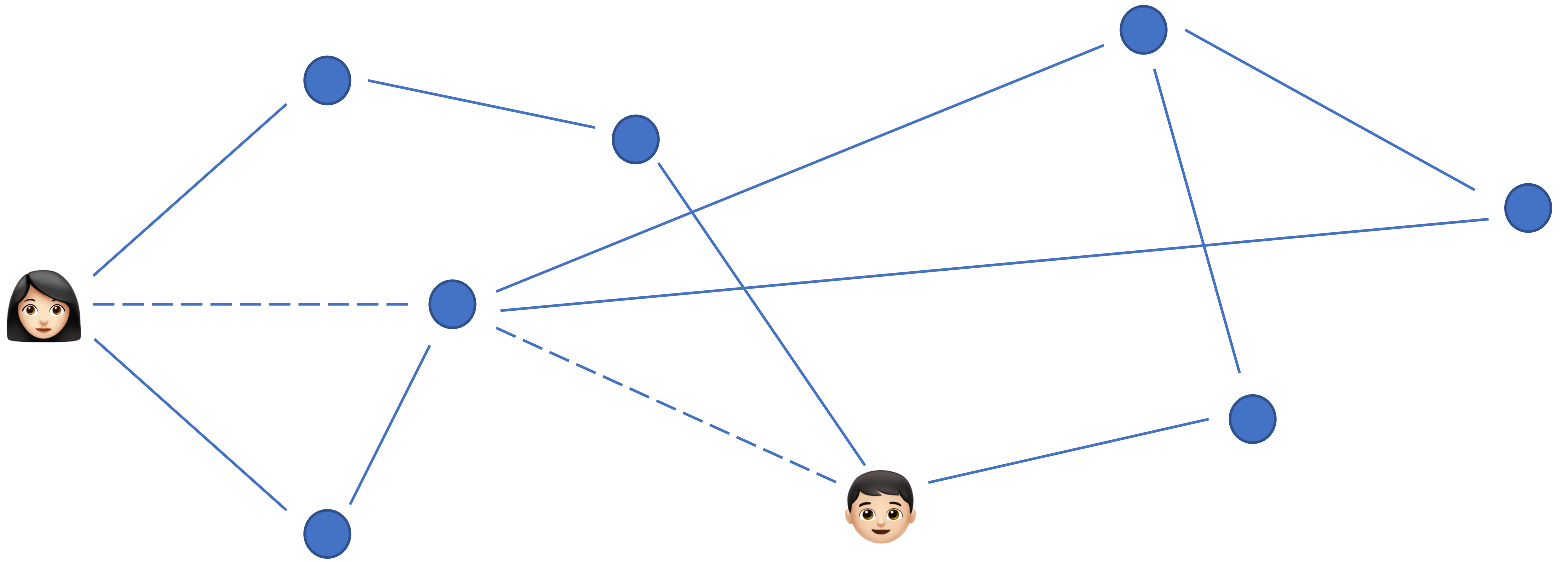
Background

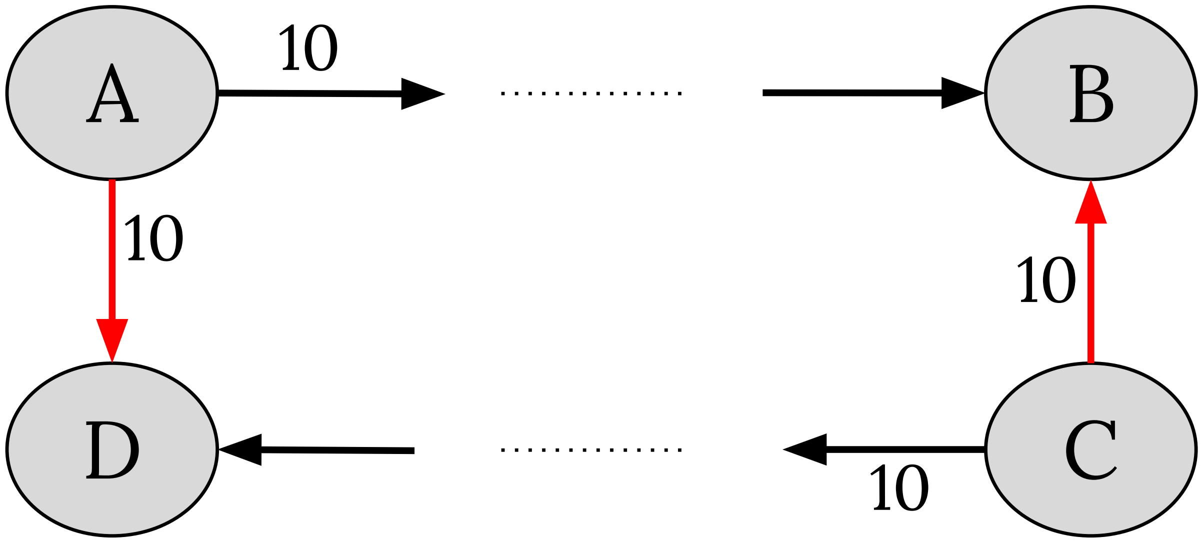
- PCNs: layer 2 solutions to improve scalability of blockchains
- Intermediary nodes on a payment path charge a routing fee



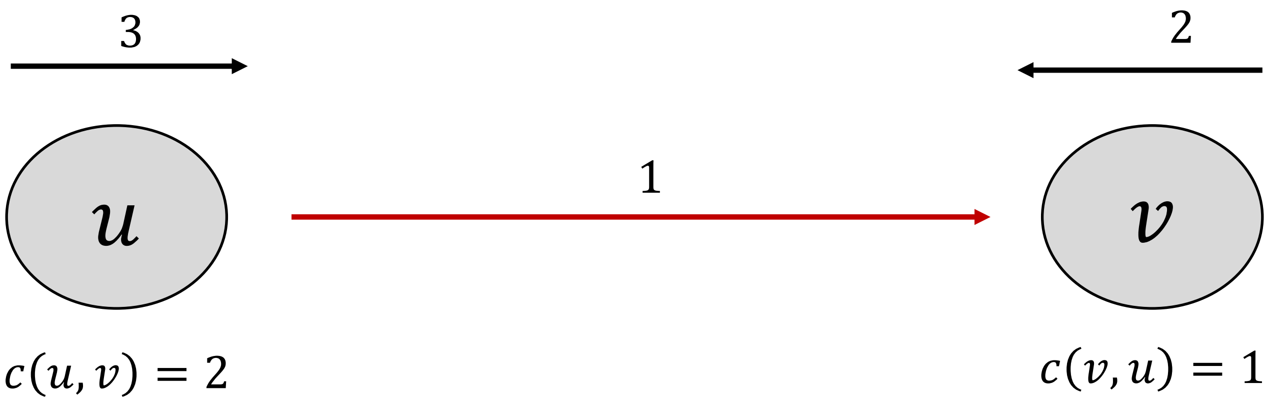
Transaction aggregation in PCNs

- Finding a set of channels which execute as many transactions as possible
  - Take into account both input transactions as well as the topology of the PCN
- Added benefit to users compared to sequential/individual execution

Motivating example 1



Motivating example 2



Our contribution

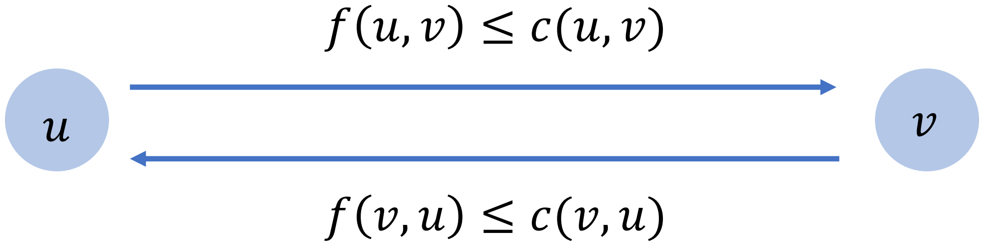
Wiser is the first solution that performs transaction aggregation in PCNs that satisfies the following properties:

1. Computational feasibility
2. Balance security
3. Optimality
4. Cost efficiency
5. Privacy

Computational problem definition

$G = (V, E), |V| = n, |E| = m$

- Flow vector f $= \big(f(e)\big)_{e \in E}, 0 \leq f(e) \leq c(e)\ \forall e \in E$



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- Flow vector f $= \left(f(e)\right)_{e \in E}, 0 \leq f(e) \leq c(e)\ \forall e \in E$
- List of transactions $T = \{t_1, t_2, \dots, t_k\}$

$$t_i = [0, \dots, w_{sender}, \dots, -w_{receiver}, \dots, 0]$$

- Demand vector $d = \sum_{t \in T} t$

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- Demand vector $d = \sum_{t \in T} t$
- A flow f routes d if $\forall\ v$,

$$\sum_{(v,u) \in E} f(v,u) - \sum_{(u,v) \in E} f(u,v) = d(v)$$

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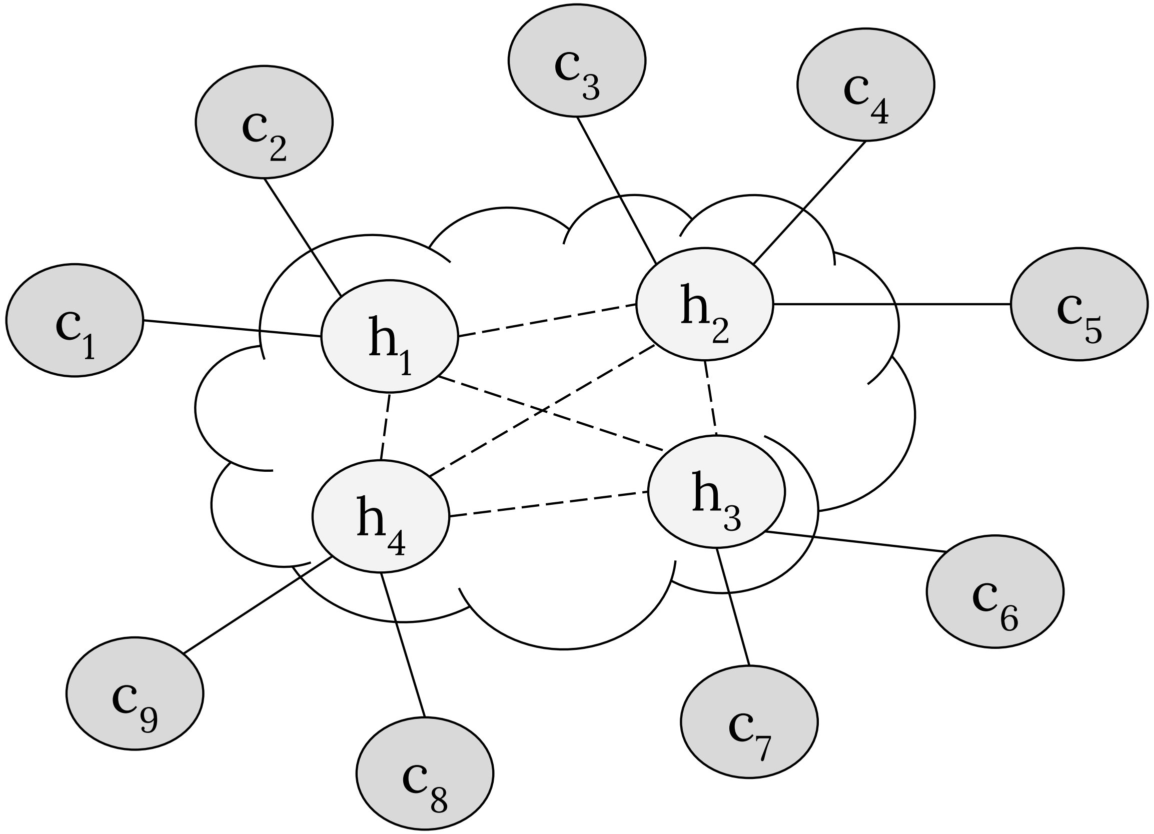
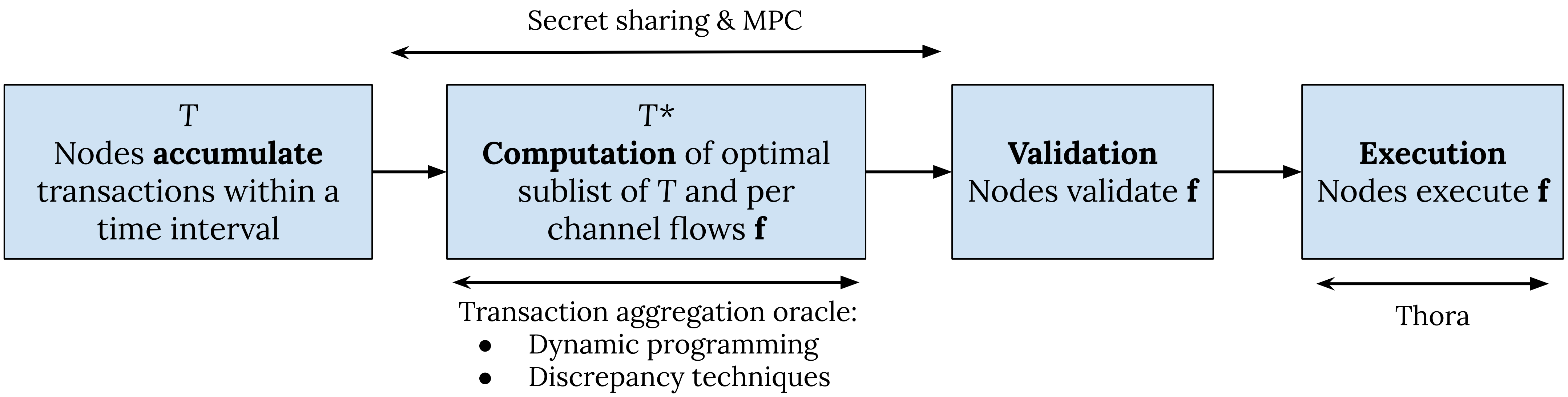
Goal: find feasible subset $T' \subset T$ such that $\sum_{t_i \in T'} |t_i|$ is maximised

PCN model



Wiser protocol implementation



Secret sharing & MPC

T
Nodes **accumulate** transactions within a time interval

*T**
Computation of optimal sublist of *T* and per channel flows **f**

Validation
Nodes validate **f**

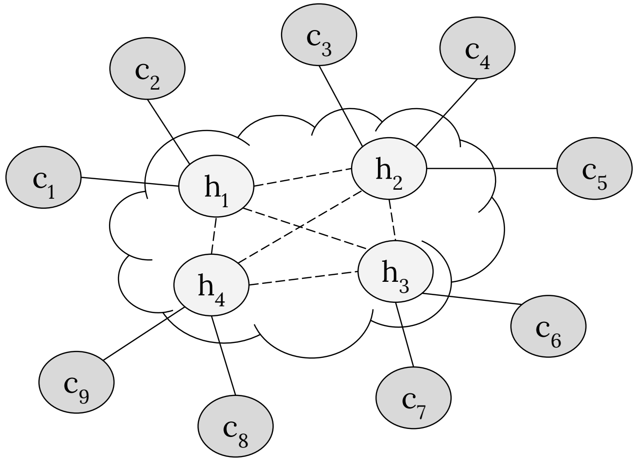
Execution
Nodes execute **f**

Transaction aggregation oracle:

- Dynamic programming
- Discrepancy techniques

Thora

Flow computation phase

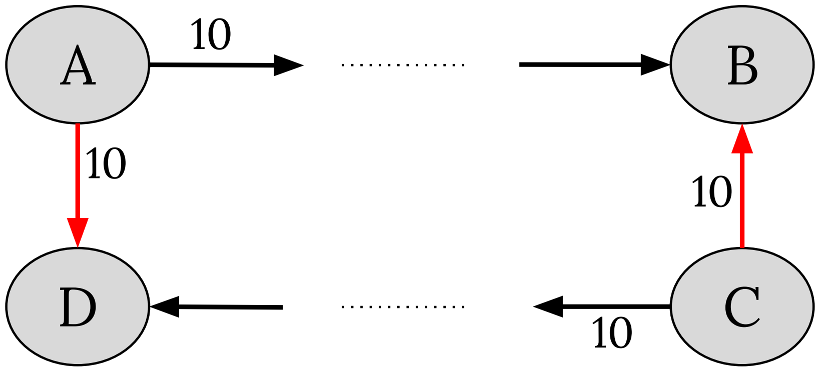


- MPC delegates sampled randomly from hubs
    - Prevents Sybil attacks
    - Sufficient computational and financial resources
- Secret sharing of transactions and channel balances to delegates
- Oracle to solve the computational problem
    - MPC so efficiency is important
    - Convert problem to integer program and use result by Eisenbrand and Weismantel[1] to solve in time linear in number of transactions and exponential in number of hubs.

[1] Eisenbrand and Weismantel, https://arxiv.org/abs/1707.00481

Atomic flow execution

- Typical HTLC based solutions require connectivity and locks payments for time linear in length of the path
- Flow output might involve disconnected components of network
- Thora[1]: multi-channel atomic updates in constant time



[1] Aumayr, Abbaszadeh, Maffei, https://eprint.iacr.org/2022/317

Analysis of Wiser

1. Computational feasibility
2. Balance security
3. Optimality
4. Cost efficiency
5. Privacy

Theorem: The transaction aggregation problem can be solved in time $O\left(k(h\Delta)^{h^2}\right)$

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Follows from atomic updates of Thora

Analysis of Wiser

1. Computational feasibility
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Follows from correctness of optimization solver

Analysis of Wiser

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Follows from the fact that fee function satisfies triangle inequality

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Follows from security guarantees of the MPC protocol

Conclusion

- First solution that performs transaction aggregation in PCNs that is computationally feasible, balance secure, optimal, cost efficient, and private
- Future work:
  1. Designing computationally tractable protocol for other topologies
  2. Cross-chain aggregation

Thank you!

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